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Symposium on Cooling Water Intake Technologies to Protect Aquatic Organisms

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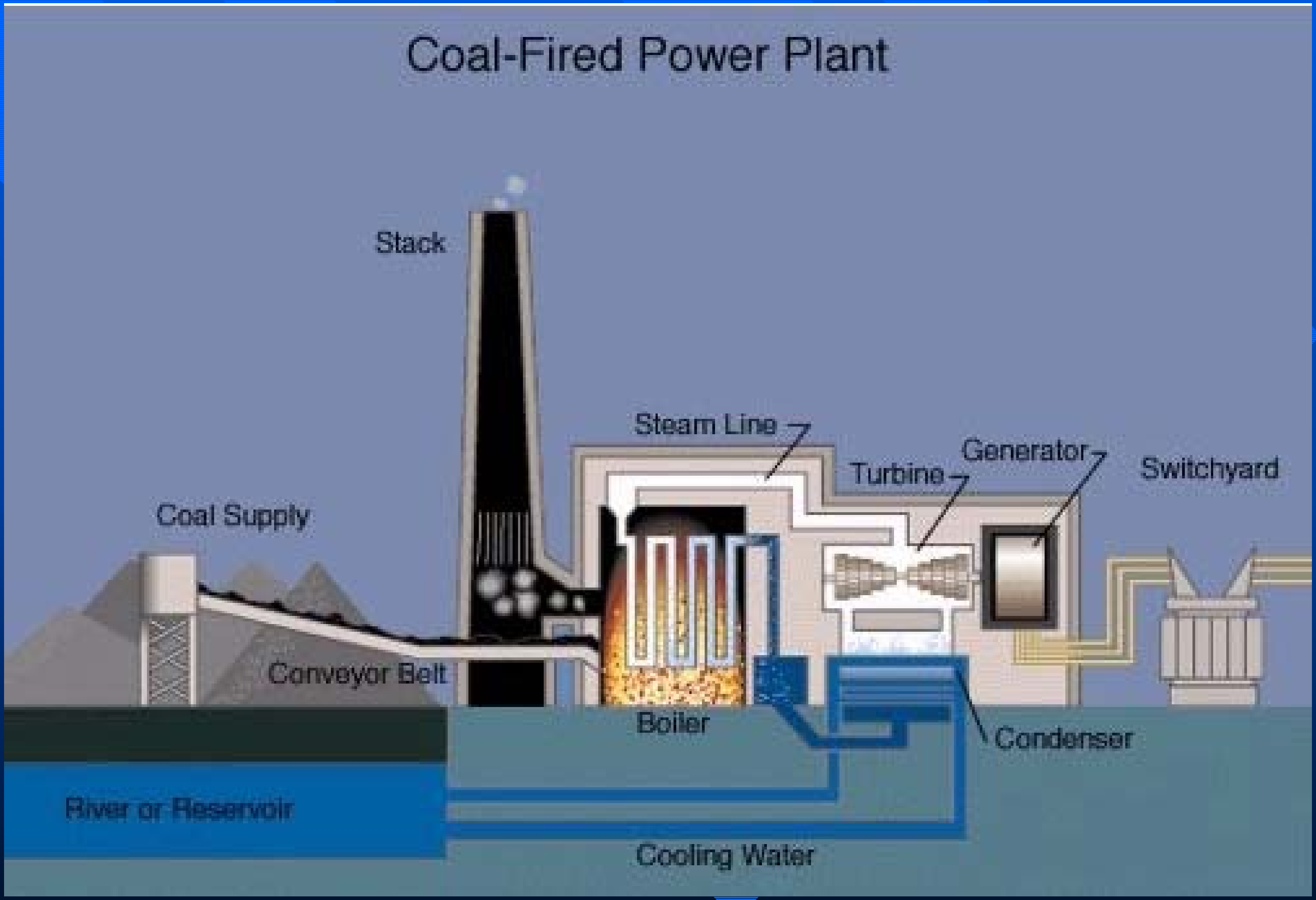
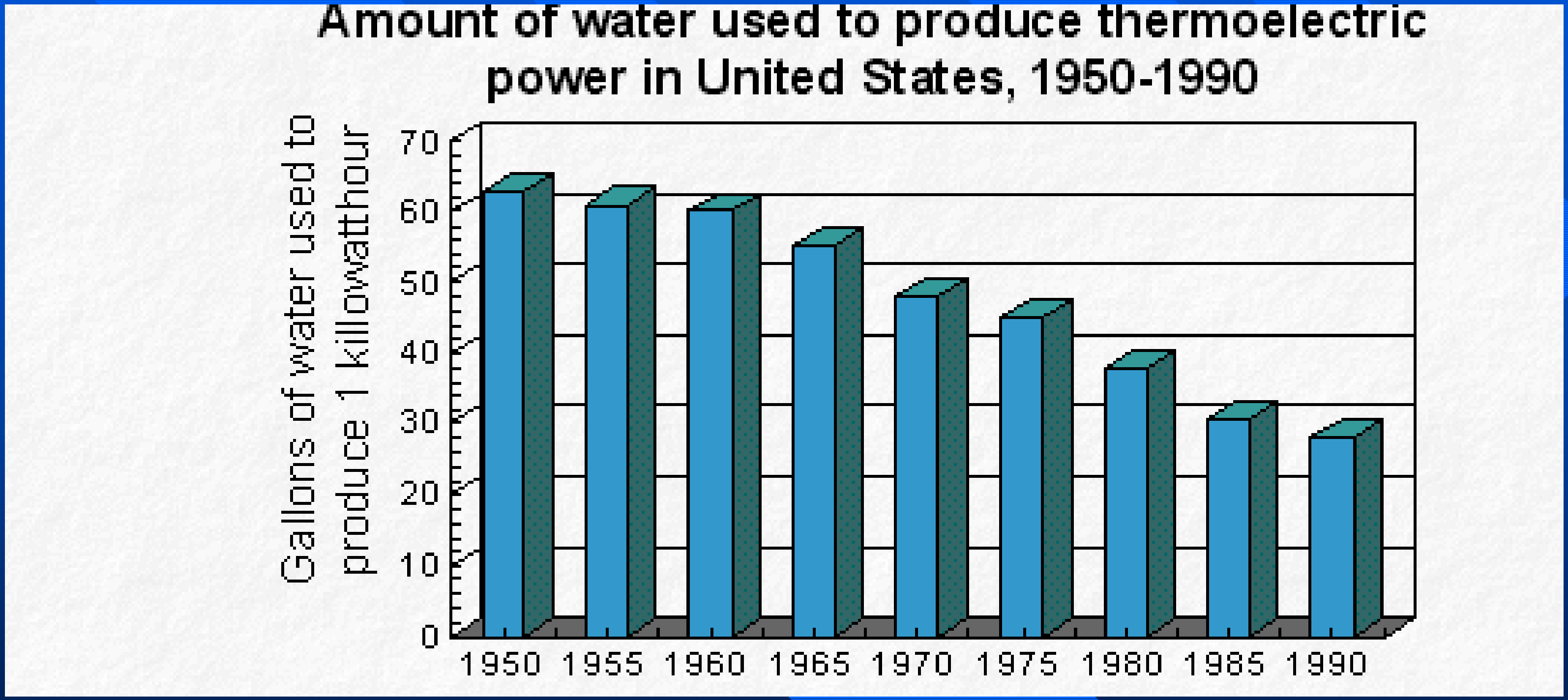
Introduction



Introduction (Continued)

- Power generated from fossil fuels is dependent on water.
- On average, approximately 28-33 gallons of water are required for each kWh of power produced from coal.
- About 70 trillion gallons of water are consumed or impacted annually in the United States to produce energy.

Introduction (Continued)



- *Source: http://wwwga.usgs.gov/edu/graphicshtml/ptratioyears.html*

Introduction (Continued)

- Why water use went down?
- Part of the answer is the use of cooling towers
- This presentation is about modeling cooling tower costs

What Is a Model?

- Model: A fact-net founded on innate ideas and inputs
  - Innate ideas: A priori knowledge, principles, or theoretical truths
  - Inputs: Experimental observations or data points

Cost Estimation Methods

- Case study-based
  - Uses costs of actual project to estimate costs of similar project
- Indirect engineering-based (parametric method)
  - Uses parameters that reflect project size and scope to estimate costs
- Direct engineering-based
  - Uses engineering designs, drawings, schematics and specifications to estimate costs
- Survey-based
  - Uses surveys of actual projects to provide cost data

Types of Cooling Systems

- Once-through
  - Cooling water makes single pass through condenser and is then discharged
- Recirculating
  - Cooling water passes through condenser, is cooled in cooling tower, and then recirculated to condenser

Types of Cooling Towers

- Wet cooling tower
  - Most common type
  - Consumes roughly 5% flow of once-through
- Dry cooling tower
  - Less efficient, larger, more costly than wet towers
  - Consumes negligible water
- Hybrid tower
  - Combines dry heat exchange surfaces with standard wet towers
  - Mostly used where plume abatement required

Factors Affecting Cooling Tower Costs

- Condenser heat load and wet bulb temperature
  - Determines size of tower needed
- Plant fuel type and age/efficiency
  - Thermal efficiency varies greatly by plant type
  - Older plants typically have lower thermal efficiencies
- Site topography
  - Can affect tower height, shape and location
  - Difficult subsurface conditions can significantly increase costs
- Material used for tower construction

Relative Trends in Tower Costs by Material

Capital	Operation	Maintenance	Useful Life (yrs)	Cost Increase
Concrete	Douglas Fir	Douglas Fir	30 (Douglas Fir)	
Steel	Redwood	Redwood	40 (Redwood)	
Redwood	Steel	Steel	17 (Steel)	
Fiberglass	Fiberglass	Concrete	50 (Concrete)	
Douglas Fir	Concrete	Fiberglass	30 (Fiberglass)	

Model Development

- Contacted cooling tower vendors
  – Costs as function of recirculating flow, delta
- Researched literature
  – Cost factors for various tower types, features
- Calculated costs for various flows, tower types, tower features
- Developed best-fit curves, equations for calculated costs

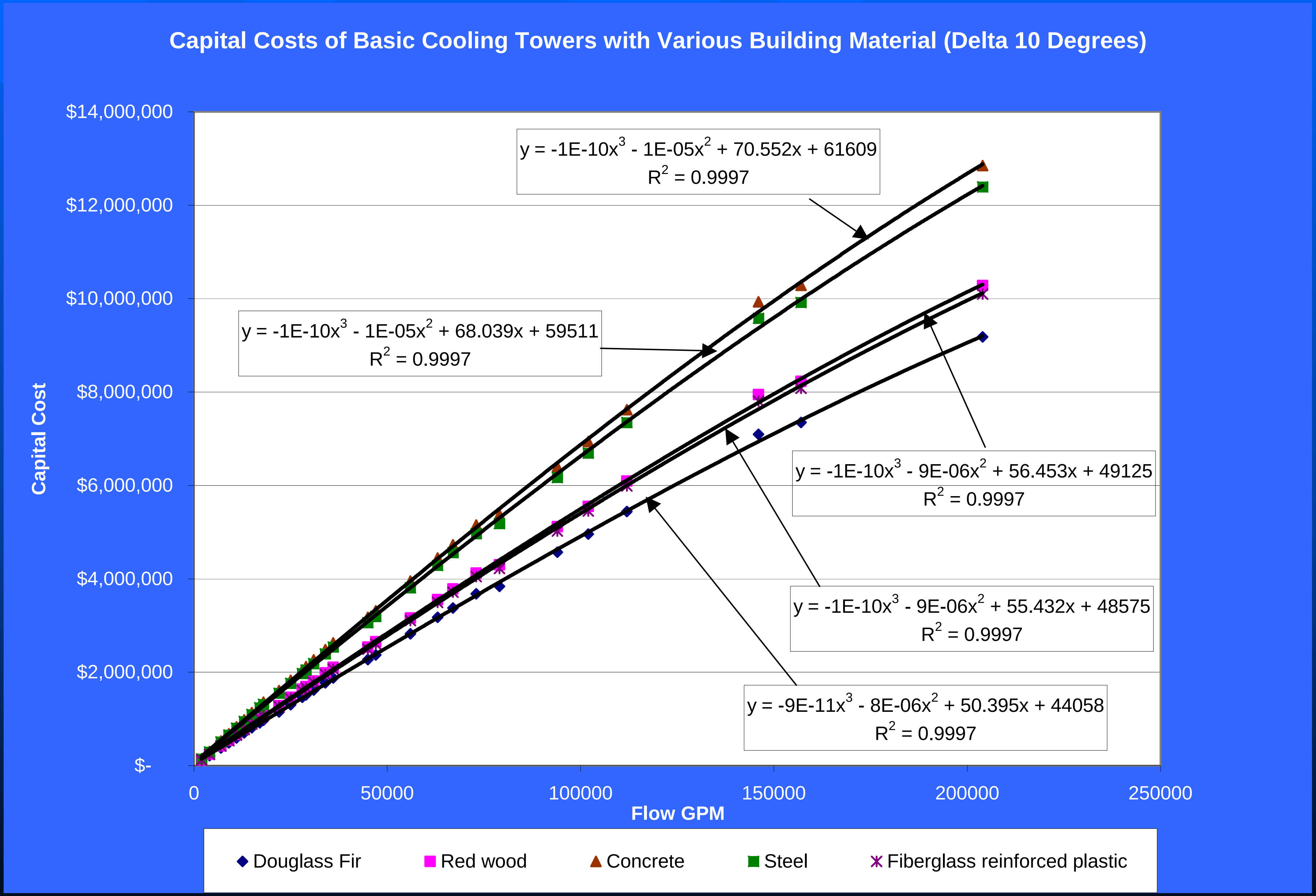
Cost Factors for Tower Types, Features[1]

Tower Type	Capital Cost Factor (%)	Operation Cost Factor (%)
Douglas Fir	100	100
Redwood	112[2]	100
Concrete	140	90
Steel	135	98
Fiberglass Reinforced Plastic	110	98
Splash Fill	120	150
Non-Fouling Film Fill	110	102
Natural Draft (Concrete)	175	35
Hybrid (Plume Abatement)	250-300	125-150
Dry/Wet	375	175
Air Condenser (Steel)	250-325	175-225
Noise Reduction (10dBA)	130	107

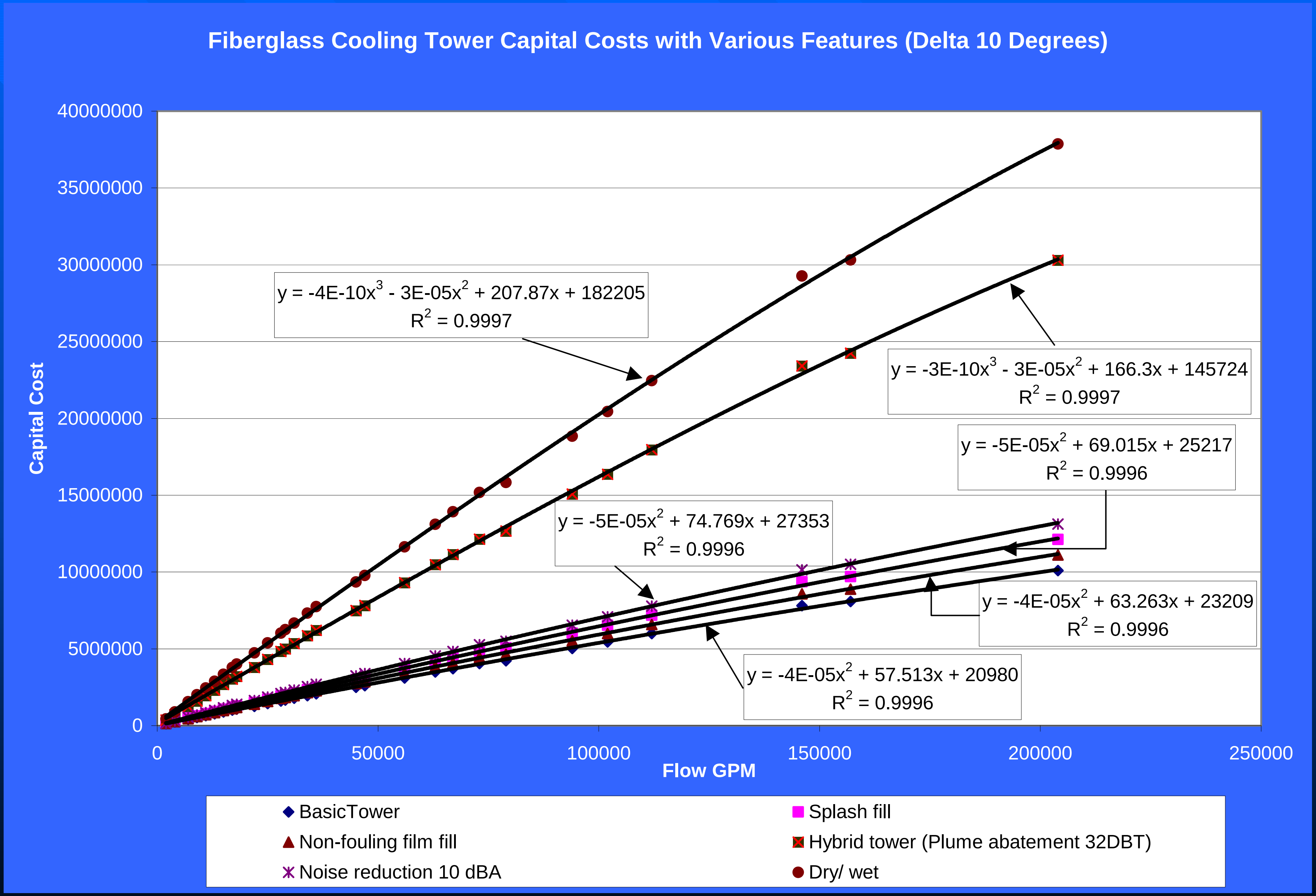
[1]Relative to Douglas Fir tower costs.

[2]Redwood costs may be higher because redwoods are protected species, particularly in NW.

Source: Mirsky et al. (1992), Mirsky and Bauthier (1997), and Mirsky (2000).

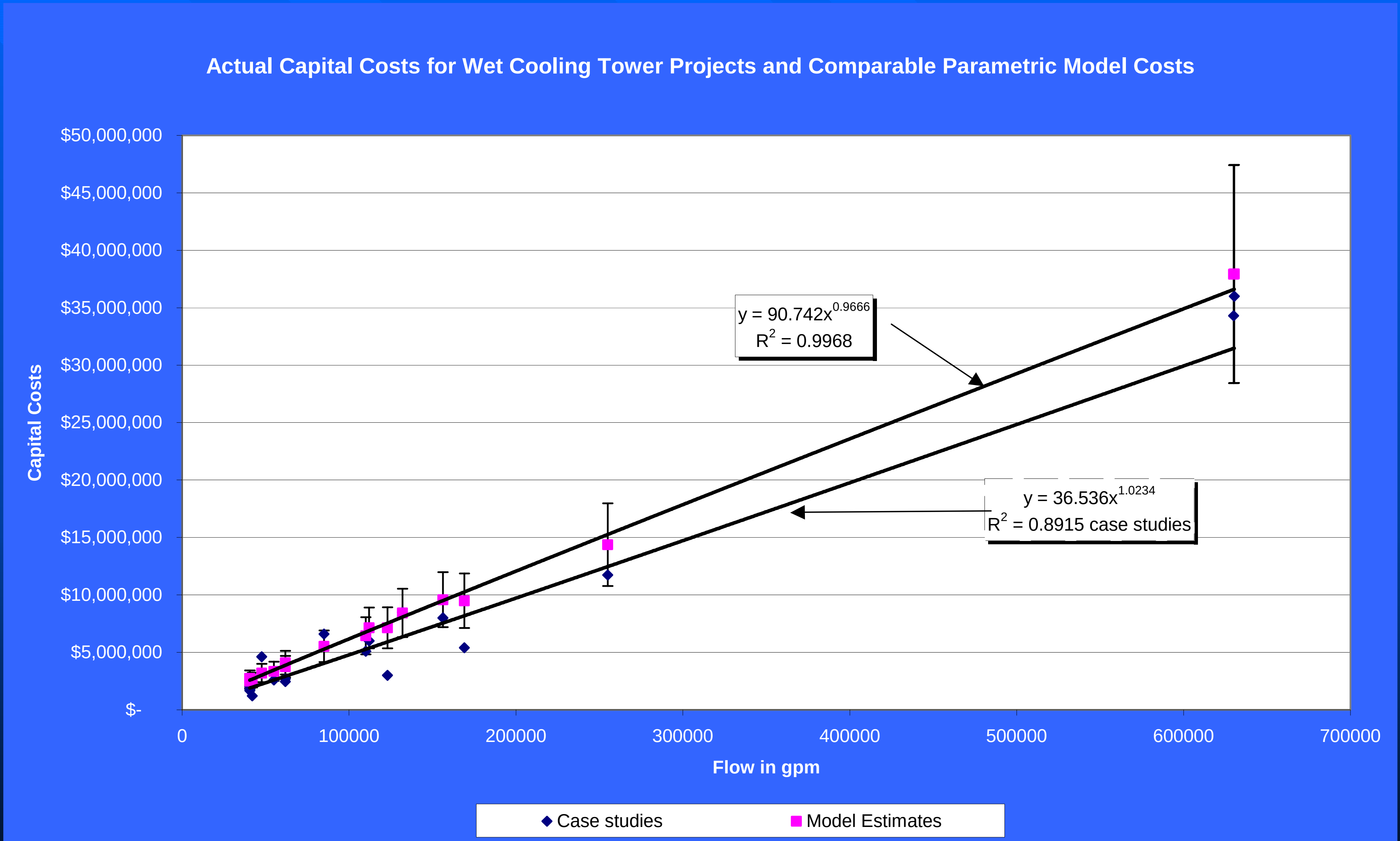


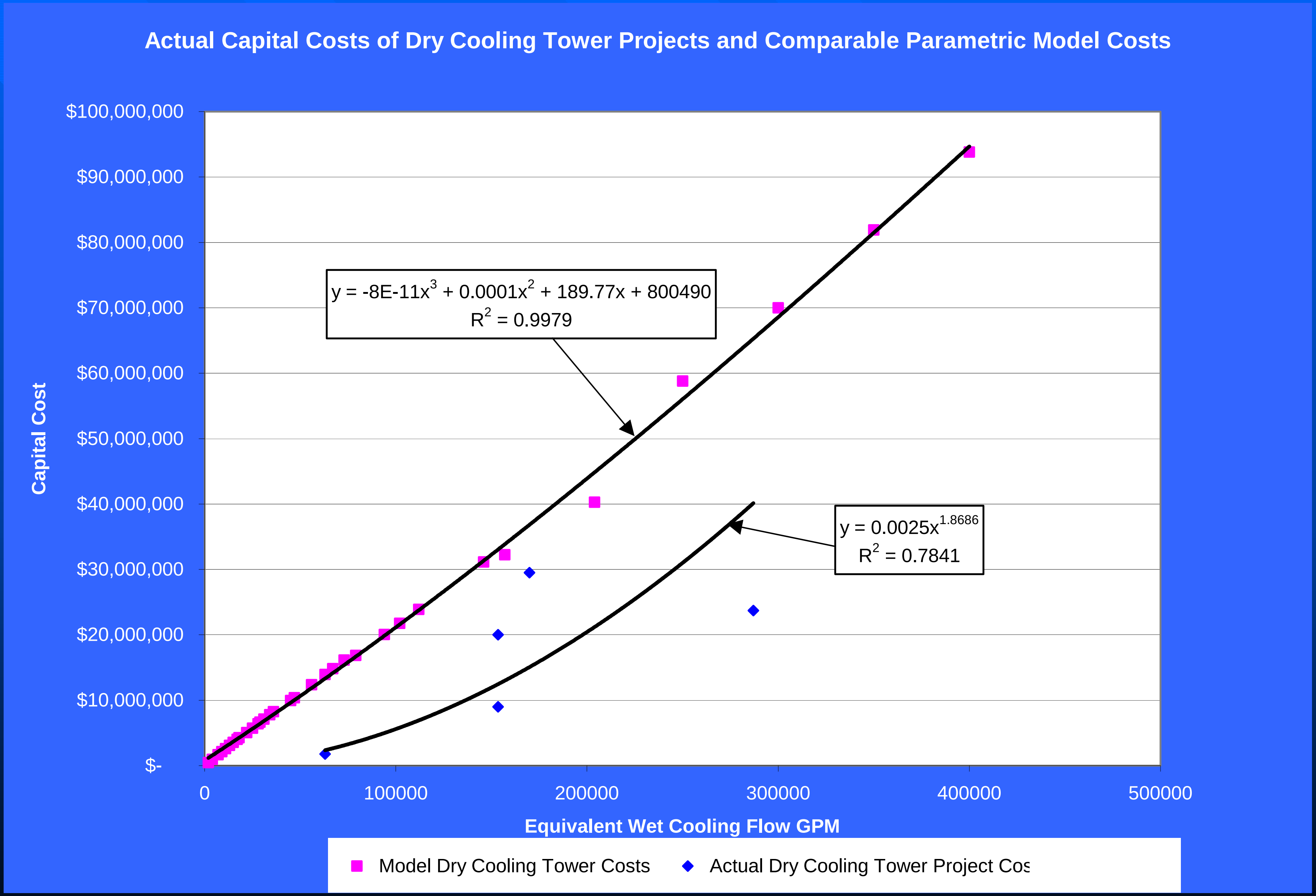
Capital Costs of Basic Cooling Towers with Various Building Material (Delta 10 Degrees)
Capital Cost
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$-
0
50000
100000
150000
200000
250000
Flow GPM
y = -1E-10x3 - 1E-05x2 + 70.552x + 61609
R2 = 0.9997
y = -1E-10x3 - 1E-05x2 + 68.039x + 59511
R2 = 0.9997
y = -1E-10x3 - 9E-06x2 + 56.453x + 49125
R2 = 0.9997
y = -1E-10x3 - 9E-06x2 + 55.432x + 48575
R2 = 0.9997
y = -9E-11x3 - 8E-06x2 + 50.395x + 44058
R2 = 0.9997
Douglass Fir
Red wood
Concrete
Steel
Fiberglass reinforced plastic


Fiberglass Cooling Tower Capital Costs with Various Features (Delta 10 Degrees)
Capital Cost
Flow GPM
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
0
50000
100000
150000
200000
250000
y = -4E-10x3 - 3E-05x2 + 207.87x + 182205
R2 = 0.9997
y = -3E-10x3 - 3E-05x2 + 166.3x + 145724
R2 = 0.9997
y = -5E-05x2 + 69.015x + 25217
R2 = 0.9996
y = -5E-05x2 + 74.769x + 27353
R2 = 0.9996
y = -4E-05x2 + 63.263x + 23209
R2 = 0.9996
y = -4E-05x2 + 57.513x + 20980
R2 = 0.9996
BasicTower
Splash fill
Non-fouling film fill
Hybrid tower (Plume abatement 32DBT)
Noise reduction 10 dBA
Dry/ wet

Model Verification

- Contacted cooling tower vendors for case studies
  - Costs for actual projects
  - Prices for bid projects
  - 11 wet tower projects, 5 dry tower projects
- Case study costs lower than model costs
  - True even for projects with unusual site-specific factors (custom-built towers, difficult construction conditions, accelerated schedules)


Actual Capital Costs for Wet Cooling Tower Projects and Comparable Parametric Model Costs
$50,000,000
$45,000,000
$40,000,000
$35,000,000
$30,000,000
$25,000,000
$20,000,000
$15,000,000
$10,000,000
$5,000,000
$-
Capital Costs
0
100000
200000
300000
400000
500000
600000
700000
Flow in gpm
y = 90.742x^0.9666
R^2 = 0.9968
y = 36.536x^1.0234
R^2 = 0.8915 case studies
Case studies
Model Estimates


Actual Capital Costs of Dry Cooling Tower Projects and Comparable Parametric Model Costs
Capital Cost
$100,000,000
$90,000,000
$80,000,000
$70,000,000
$60,000,000
$50,000,000
$40,000,000
$30,000,000
$20,000,000
$10,000,000
$-
0
100000
200000
300000
400000
500000
Equivalent Wet Cooling Flow GPM
y = -8E-11x3 + 0.0001x2 + 189.77x + 800490
R2 = 0.9979
y = 0.0025x1.8686
R2 = 0.7841
Model Dry Cooling Tower Costs
Actual Dry Cooling Tower Project Cos

Conclusions

- Model gives tower cost estimates that are conservative on high side
  - Holds true even for projects with difficult site-specific factors

Future Directions/Research Needs

- Reducing water use requirements
  - Improved wet cooling system efficiency
  - Improved dry cooling system efficiency
  - Improved water recycling processes
  - New generating and cooling media
  - Improved boilers to use low quality water
  - Technologies to reduce cooling tower evaporative losses

Future Direction/Research Needs

- Improving power generation with same or reduced water use
  - Improved turbine efficiency
  - Improved process control
  - Combined power generating cycles
  - Advanced steam power plant design
  - Systems to utilize evaporated water energy and exhaust gases energy
  - Improved water treatment